SEARCHING FOR INTRINSIC VARIATIONS IN ECLIPSING BINARY STARS

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Abstract

Using a database of nearly 4000 visual estimates made by the author between 1967 and 1993, evidence for intrinsic variations on a time scale of years is sought after in 64 eclipsing binary stars. While none is found for most stars, certain objects warrant further investigation.

1. Introduction

The light of an eclipsing binary (EB) star system changes most notably during eclipses—an extrinsic effect due to the chance alignment of the orbital plane with our line of sight. Even outside of eclipse, however, light variations can occur due to tidally or rotationally distorted stellar shapes (Beta Lyrae-type light curves) or the effect of one star's radiation on the other. Together with the periodic eclipses, these last two (also predictable) effects define the light curve, which typically is identically exhibited cycle after cycle. A few EB stars, however, do not exhibit this typical behavior: with changes in their light curves, they are said to show intrinsic variations.

EB star observing programs utilizing estimates made visually with small telescopes — most notably those conducted by the AAVSO and the *Bedeckungsveränderlichen Beobachter der Schweizerischen Astronomishen Gesellschaft* (BBSAG)—have concentrated on deriving times of EB minima and assessing period changes. While the thrust of such efforts is appropriate, participating observers should nonetheless realize that comparing observing runs on the same star (made at different times) can be worthwhile in detecting EBs with intrinsic variations. Three decades ago, when the AAVSO EB program began, the number of EBs known to fit into this category was small and lists of such objects (Wood 1963) were rather short. As more systems have been studied photoelectrically, however, the situation has changed.

Besides individual EBs found to warrant inclusion in such lists, two whole classes of variable stars—RS CVn stars and W Ser stars—have been recognized which contain many such EB candidates for inclusion. The light curves of RS CVn stars are distorted by a migrating wave which typically causes variations of 0.05 to 0.25 magnitude, although intrinsic variations in one star of up to 0.5 magnitude (Doyle *et al.* 1988) or 0.6 magnitude (Nolthenius 1991) in V have been reported. As for W Ser, the prototype of a group of active Algol systems known as "Serpentids," its brightness can change by "over~0.5 mag... [within] one observing season and also from year to year" (Guinan 1989).

While a complete listing of EBs known to exhibit intrinsic variations will not be presented, EBs whose amplitude is known (or suspected) to have changed (Table 1) and AAVSO EB program stars with intrinsic variations or changing light curves (Table 2) are listed (with annotations). Each of these lists contains an EB whose intrinsic variations were first detected through visual means. SZ Oph's behavior was noted by BBSAG observers Locher and Diethelm (BBSAG 1980), and this object apparently awaits photoelectric study; U CrB's intrinsic variations were suspected based on visual estimates made in the 1930s (Lause 1938).

Table 1. Eclipsing Binaries with Changed Amplitudes
(extended from shorter list in Schaefer and Fried 1991)

IU Aur —	amplitude increase from 0.16 magnitude in 1892 to 0.74 in 1985; changes due to nodal motion caused by 3rd star
SS Lac —	primary and secondary eclipses of 0.5 magnitude amplitude reported (since 1890) by several observers had disappeared by 1949-1950; photoelectric observations in 1980s showed no variations (Schiller 1985)
V651 Mon —	central star of NGC 2346; was constant, began having deep eclipses caused by dust cloud ejected by companion
AY Mus —	Algol-type star; amplitude of 0.33 magnitude in early 1900s; had stopped eclipsing by 1973
SZ Oph —	large amplitude increase visually noted during 1979–1980 (termed "amazingly deep and narrow") when compared with shallower minima seen during 1974–1978 by two observers (BBSAG 1980)
RW Per —	B-magnitude amplitude has decreased from 3.2 in 1890s to 1.75 in 1990s (cause: nodal variation due to 3rd star?)

Obviously, detecting and studying small intrinsic variations in EBs from visual estimates alone will be fraught with difficulties and uncertainties. The random and systematic errors plaguing such estimates, notably color error and angle error, have been described elsewhere (Williams 1987). Attempting to compare EB estimates of different observers using different instruments and possibly different comparison star sequences, with differing eye sensitivities, seeing conditions and personal idiosyncracies may be more trouble than it's worth! Yet a careful observer can detect a visual brightness difference of less than 0.05 magnitude. Such an observer can also work to minimize or control some of the factors which introduce the errors or uncertainties cited above. And, happily, no one is suggesting that visual estimates alone be relied on for such EB intrinsic variation studies. From such visual efforts, a list of EBs suspected of showing intrinsic variations or varying light curves could be assembled for subsequent investigation by photoelectric means. This paper will provide such a list based on my own visual observations.

Table 2. Some AAVSO EB Program Stars with Intrinsic Variations

U Cep —	"the normal 2 hour totality shrinks or sometimes disappears, turning the light curve into a partial eclipse" (Hall and Keel 1977)
U CrB —	substantial eclipse depth variations at all wavelengths, maximum varies by up to 5% in near-UV; 0.2 to 0.25 magnitude variations in V are largest found (van Ghent 1991)
CG Cyg —	RS CVn star; its V magnitude at maximum brightened by 0.2 magnitude over 1969-1981; "light curve is highly variable and does so on a short time scale" (Naftilan 1987)
U Sge —	at total eclipse, variations in minimum brightness noted; change of 0.138 magnitude in V occurred in 7.3 years (Olson and Etzel 1993)
RW Tau —	at total eclipse, variations in minimum brightness noted; change of 0.331 magnitude in V occurred in 11.4 years (Olson and Etzel 1993)
X Tri —	at total eclipse, variations in minimum brightness noted; change of 0.303 magnitude in V occurred in 11.0 years (Olson and Etzel 1993)

2. Observations

Since 1967 I have visually timed minima of EB stars, typically using a 15 cm f/10 reflector (for all except the brightest objects). This work has been concentrated in three time frames and settings: (1) 1967–1968 from a (moderately bright sky) suburban southern California location, (2) 1984–1985 from a remote (very dark sky) northern Arkansas location, and (3) 1992–1993 from a semi-rural (moderately dark sky) central Arkansas location. During these years my eyesight has changed very little.

In autumn 1992, after comparing observations of the short period EB star RS Scuti I made in 1984 and 1992, I became interested in EB intrinsic variations. Having seemingly detected such a variation in RS Sct (Cook 1993), I began looking for evidence of these variations in other stars. In this regard, Table 3 summarizes my EB visual observations. Included are stars for which I recorded at least one minimum in two or more of the three indicated time frames (as above but extended slightly). Data on 64 EB stars, covering over 300 minima and involving nearly 4000 visual estimates, are presented. Approximately half of these stars are AAVSO EB program stars.

3. Discussion of the Observations

Based on the data in Table 3, how many of the 64 EB stars need to be included in a list of those showing intrinsic variations? Given the difficulties inherent in photometry by the means of visual estimates, this is a difficult question to answer. Perhaps none, perhaps several. In examining the numerical data for individual stars in Table 3, objects whose magnitudes at minimum (or maximum, although this typically wasn't well determined) vary by more than some threshold amount X would seem to be candidates for our list. What value of X should we pick?

While the entries in Table 3 are to the nearest hundredth of a magnitude, obviously these visually-derived averages are not that accurately determined. Typically, my visual estimates are rounded to the nearest 0.025 to 0.05 magnitude (the nearest half-step or step where the typical step size is 0.05 to 0.06 magnitude). Despite this seeming accuracy, I am well aware of the pitfalls that can plague even the most careful visual observers. Despite taking care to minimize such errors, I would prefer to place X at a level that would insure one is out of the "noise" that plagues visual estimates. Since I have seen an EB star's brightness appear to change by as much as 0.30 magnitude upon crossing the meridian (and necessitating a change in the orientation of how my eyes were viewing its field) I can't pick X any smaller than this. Perhaps it should be even larger? (Williams [1987] has carefully documented such a 0.25 magnitude angle error).

Instead of settling on a single value of X, I have decided to interpret "variations" based on visual estimates by assigning them to the following categories:

CATEGORY	"X"	DEFINITION
1	< 0.30 mag.	"NOISE"— ignore any suggested variation
2	0.30–0.50 mag.	"PROBABLY NOISE?"— some objects may warrant followup
3	> 0.50 mag.	"WARRANTS FURTHER INVESTIGATION"—object needs attention from photoelectric observers

Of the 64 stars in Table 3, only RS Sct (well observed, see Cook 1993) and XZ Aql (poorly observed) have shown "variations" placing them in category 3. In addition to RS Sct, Table 4 lists 8 EB stars where my observations suggest a long-term intrinsic variation at the category 2 level. In addition to XZ Aql, Table 5 lists 5 EB stars where my observations suggest a short-term intrinsic variation at the category 2 level. Before briefly discussing these seeming variations, note that observed minimum brightness for

Table 3. Author's visual observations and estimates of EB stars to assess possible intrinsic variations.

STAR	TYPE[1]	PERIOD (DAYS)	GCVS TYPES	GCVS MAX	GCVS MIN	1967–72 #MIN/ #EST	1967–72 AVE. MAX	1967–72 AVE. MIN.	1984–87 #MIN/ #EST	1984–87 AVE. MAX	1984–87 AVE. MIN.	1989–93 #MIN/ #EST	1989–93 AVE. MAX	1989–93 AVE. MIN.	COMMENTS[2]
RT And	EA/DW/RS	0.629	F8V	8.55	9.47	3/31	9.37	10.17	0/0	—	—	2/22	9.75	10.15	seq prob?
TW And	EA/SD	4.122	F0V+K0	8.8	10.86	0/0	—	—	1/15	—	37	1/15	—	38	SS=.10 mag
XZ And	EA/SD:	1.357	A4IV-V	10.02 P	12.99 P	1/14	10.0	12.2	1/13	10.0	11.85	1/12	10.2	11.9	
AB And	EW/KW	0.332	G5+G5V	9.50	10.32	3/34	9.3	10.15	3/33	9.45	10.43	2/17	9.55	10.48	
XZ Aql	EA/SD:	2.139	A2	10.1 P	11.4 P	0/0	—	—	1/17	9.85	11.2	2/23	9.6	11.5 *	
KP Aql	EA/DM	3.367	F+F	9.7 B	10.43 B	0/0	—	—	1/8	—	10.45	1/1	—	10.4	
OO Aql	EW/DW:	0.506	G5V	9.2	9.9	4/43	9.7	10.8	7/75	9.75	10.85	2/17	9.95	10.75	
V343 Aql	EA/SD:	1.844	A0V	10.6 P	12.3 P	0/0	—	—	1/12	—	12.5	1/15	—	12.8	
V346 Aql	EA/SD	1.106	A0V	9.0 P	10.1 P	3/39	9.3	10.45	3/38	9.35	10.65	2/22	9.55	10.68	
CX Aqr	EA/SD	0.556	F2P	10.55	11.75	0/0	—	—	4/42	10.85	11.85	1/14	10.75	11.7	
WW Aur	EA/DM	2.525	A3M:+A3M:	5.79	6.54	5/51	—	6.45	5/54	—	6.41	2/23	—	6.48	
ZZ Boo	EA/DM	4.992	F2+F2V	6.79	7.44	1/9	—	7.25	0/0	—	—	1/12	—	7.25	
SV Cam	EA/DW/RS	0.593	G5V+G3V	8.40	9.11	6/60	8.95	9.65	0/0	—	—	3/37	8.86	9.59	
RZ Cas	EA/SD	1.195	A2.8V	6.18	7.72	7/77	(6.4)	7.81	4/44	(6.55)	7.88	5/61	(6.5)	7.81	
TV Cas	EA/SD	1.813	B9V+F7IV	7.22	8.22	3/37	—	8.38	1/12	—	8.4	3/26	—	8.4	
U Cep	EA/SD	2.439	B7VE+G8III	6.75	9.24	3/43	—	9.4	0/0	—	—	2/15	—	9.15	
CQ Cep	EB/DM/WR	1.641	WN5.5+07	8.63	9.12	2/23	8.88	9.4	0/0	—	—	1/25	8.85	(9.3)	
EK Cep	EA/DM	4.428	A0V	7.99 B	9.32 B	1/14	—	9.1	0/0	—	—	1/14	—	9.38	
RW Cet	EA/SD	0.975	A5	10.43 B	11.4 B	0/0	—	—	2/19	11.25	19.87	2/23	13.25	25.25	SS=.07 mag
TX Cet	EB/KE	0.7408	A2	10.9	11.47	0/0	—	—	2/21	(11)	23.12	2/24	(14)	22.5	SS=.05 mag
XY Cet	EA/DM	2.780	AM+AM	8.65	9.54	2/22	8.68	9.3	1/11	8.8	9.25	0/0	—	—	
R CMa	EA/SD	1.136	F1V	5.70	6.34	2/16	(5.95)	6.3	4/46	(5.95)	6.43	3/36	(5.95)	6.4	
YY CMi	EB	1.094	F6VN	8.33	9.13	0/0	—	—	1/12	(16)	28	1/14	(11.5)	21	SS=.066 mag
U CrB	EA/SD	3.452	B6V+F8III	7.66	8.79	1/10	(7.8)	8.8	1/14	(7.7)	8.5	1/14	(7.7)	8.5	
V Crt	EA/KE:	0.702	A6	9.9 P	10.53 P	0/0	—	—	2/20	20.8	28.8	1/11	23	29	SS=.087 mag
Y Cyg	EA/DM	2.996	B0IV+B0IV	7.30	7.90	2/28	(7.15)	7.6	4/50	(7.1)	7.6	0/0	—	—	seq prob?
CG Cyg	EA/SD/RS	0.631	G9.5V+K3V	9.73	10.86:	0/0	—	—	5/61	18.5 *	28.5	3/32	21.7 *	28	SS=.066 mag
V477 Cyg	EA/DM	2.346	A3V+F5V	8.50	9.34	0/0	—	—	1/10	(24)	36	1/10	(12)	28.5	SS=.055 mag
TY Del	EA/SD	1.191	B9	9.7	10.9	0/0	—	—	3/43	9.9	10.8	1/10	10.05	10.65	
FZ Del	EA/SD	0.783	F	10.2 P	11.3 P	0/0	—	—	3/29	10.05	11.43	2/19	10.08	11.2	
AI Dra	EA/SD	1.199	A0V	7.05	8.09	4/46	(7.4)	8.2	2/29	(7.25)	8.18	1/14	(7.25)	8.05	

S Equ	EA/SD	3.436	B9V+F9III	8.0	10.08	0/0	—	—	1/17	8.18	10.0	1/15	7.85	10.2	
YY Eri	EW/KW	0.321	G5+G5	8.1	8.80	0/0	—	—	4/43	7.5	8.38	2/22	7.65	8.3	
SZ Her	EA/SD	0.818	F0V	9.86	11.87	1/17	(10.5)	12.05	5/68	(10.58)	12.05	1/13	(10.35)	11.8	
TX Her	EA/DM	2.059	A5+F0	8.54	9.31	1/10	(6)	16	0/0	—	—	1/12	(7.5)	22	SS=.05 mag
CT Her	EA/SD	1.786	A3V	10.6 P	11.7 P	1/9	(11.2)	11.6	2/19	11.0	11.7	1/12	11.2	11.9:	
VZ Hya	EA/DM	2.904	F5V+F5V	8.96	9.68	1/10	9.2	9.9	1/9	9.3	9.85	1/12	9.25	9.73	
AV Hya	EB/KE	0.683	A1	10.2	10.77	0/0	—	—	2/21	(15)	25 *	1/7	(17)	29	SS=.05 mag
SW Lac	EW/KW	0.321	G8VP+G8VP	8.51	9.39	6/72	9.25	10.13	4/57	9.4	10.15	3/30	9.53	10.08	
CM Lac	EA/DM	1.605	A2V+A8V	8.18	9.15	1/15	8.3	9.05	0/0	—	—	1/11	8.25	9.2	
UV Leo	EA/DW	0.600	G0V+G2V	8.90	9.56	7/74	8.55	9.1	2/24	8.4	9.2	0/0	—	—	
delta Lib	EA/SD	2.327	A0IV-V	4.91	5.90	0/0	—	—	2/23	—	5.9	2/27	—	5.9	
FL Lyr	EA/DM	2.178	G0V	9.27	9.89	1/11	8.75	9.55	0/0	—	—	2/20	9.1	9.83	
RU Mon	EA/DM	3.585	B9P	10.33	11.18	1/8	10.35	10.9:	1/8	10.65	11.0	1/10	10.55	11.2	
RW Mon	EA/SD	1.906	B9V+F8V-G0	9.26	11.51	0/0	—	—	1/8	9.9	11.3	1/12	9.9	11.5	
BB Mon	EA/KE	0.733	A0	10.6 P	11.3 P	0/0	—	—	1/9	(4)	8.25	1/15	(2.5)	6.5	SS=.10 mag
U Oph	EA/DM	1.677	B5V+B5V	5.84	6.56	1/13	(6.2)	6.7	2/23	(6.25)	6.5	2/26	(6.15)	6.61	
V451 Oph	EA/DM	2.197	B9V+A2	7.86 P	8.46 P	0/0	—	—	1/13	(24)	35	3/48	(22.4)	28.8	SS=.055 mag
ER Ori	EW/KW	0.423	F8V	9.28	10.01	1/8	(9.5)	10.15	4/46	8.93	10.0 *	4/42	8.93	10.13	
FT Ori	EA/DM	3.150	A0	9.1	9.90	0/0	—	—	1/12	17	33	1/13	14	32	SS=.044 mag
U Peg	EW/KW	0.375	F3+F3	9.23	10.07	1/13	9.9	10.45	6/63	9.9	10.5	2/16	10.0	10.55	
DI Peg	EA/SD	0.712	F4IV	9.38	10.48	0/0	—	—	4/39	9.4 *	10.25	2/23	9.65	10.43 *	
beta Per	EA/SD	2.867	B8V	2.12	3.39	2/23	—	3.4	4/50	—	3.44	1/10	—	3.33	
XZ Pup	EA/SD	2.192	A0	7.75	10.26	0/0	—	—	1/11	(19.8)	31.5	2/20	(14)	31.3	SS=.12 mag
RS Sct	EB/SD	0.664	F5	9.78	10.91	0/0	—	—	3/34	(9.7)	10.8	6/60	(10.25)	11.3	
U Sge	EA/SD	3.381	B8V+G2IV	6.45	9.28	1/15	—	9.15	2/19	—	9.18	2/29	—	9.18	
V505 Sgr	EA/SD	1.183	A2V+F6:	6.46	7.51	1/10	(6.9)	7.45	2/26	(6.75)	7.45	1/9	(6.6)	7.4	
SV Tau	EA/SD	2.167	B9+A0	9.68	10.78	0/0	—	—	1/14	(30)	36	1/16	(28)	35.5	SS=.10 mag
X Tri	EA/SD	0.971	A5V+G0V	8.55	11.27	4/57	8.97	10.93	3/40	8.95	10.92	1/10	(9.3)	11.0:	
RV Tri	EA/SD	0.754	F9+K2	11.5 P	13.3 P	0/0	—	—	2/24	(20.5)	45.5	1/10	(24)	42	SS=.044 mag
TX UMa	EA/SD	3.063	B8V+G0III	7.06	8.80	3/37	—	8.35	0/0	—	—	3/42	—	8.38	
AG Vir	EW/KE	0.643	A7-A9V	8.35	8.93	0/0	—	—	2/20	12.8	19	1/12	13	19	SS=.10 mag
Z Vul	EA/SD	2.455	B4V+A3III	7.25	8.90	1/12	—	8.6:	1/14	—	8.85	2/27	—	8.85	
BU Vul	EA/SD	0.569	G0	10.6 P	11.4 P	0/0	—	—	2/27	11.8 *	23	3/29	14.8 *	22.7	SS=.07 mag

[1] "EB" here means "eclipsing binaries with a beta Lyrae-type light curve shape," not as "eclipsing binary" is used in the text. [2] "SS" means step size; : means value cited is uncertain; * means short term intrinsic variation noted (see Table 5). All star data from 1985 GCVS (mags. are V unless noted). Mag or step in parentheses means min. or max. not determined but value shown may be at appropriate phase for comparison.

many stars was quite constant—including X Tri and U Sge, whose minimum magnitudes are known to vary slightly.

The "variations" indicated in Tables 4 and 5 for RW Cet, U CrB, and CG Cyg are not surprising since these stars are known to exhibit intrinsic variations. (See Table 2 regarding the last two stars, and see Figure 1 for observations of CG Cyg.) As for RW Cet, its maximum has varied by 0.12 magnitude in V based on photoelectric observations made 10 days or so apart (Padalia 1987). Similarly, based on physical considerations, the "variations" in AB And, ER Ori, RS Sct, and BU Vul might not be too difficult to explain if they are real. BU Vul observations are shown in Figure 2.) Each of these four systems contains a rapidly rotating star of spectral type late F or G as the brighter component of the two, which might therefore be an active dynamo star (Hall 1991), and like members of RS CVn binaries, might show variations as a result of starspot activity. As for stars in Table 3 officially classified RS CVn in the *General Catalogue of Variable Stars* (Kholopov *et al.* 1985) (GCVS), besides CG Cyg, RT And seemingly shows a variation (although there may be a comparison star problem here), while maxima and minima of SV Cam varied little, if any.

I could continue considering individual stars in Tables 4 and 5 as to whether or not intrinsic variations might be expected based on physical considerations, but this seems premature. None of the "variations" reported here have been established. Hopefully others will follow up on these suggested variations with more accurate photometry.

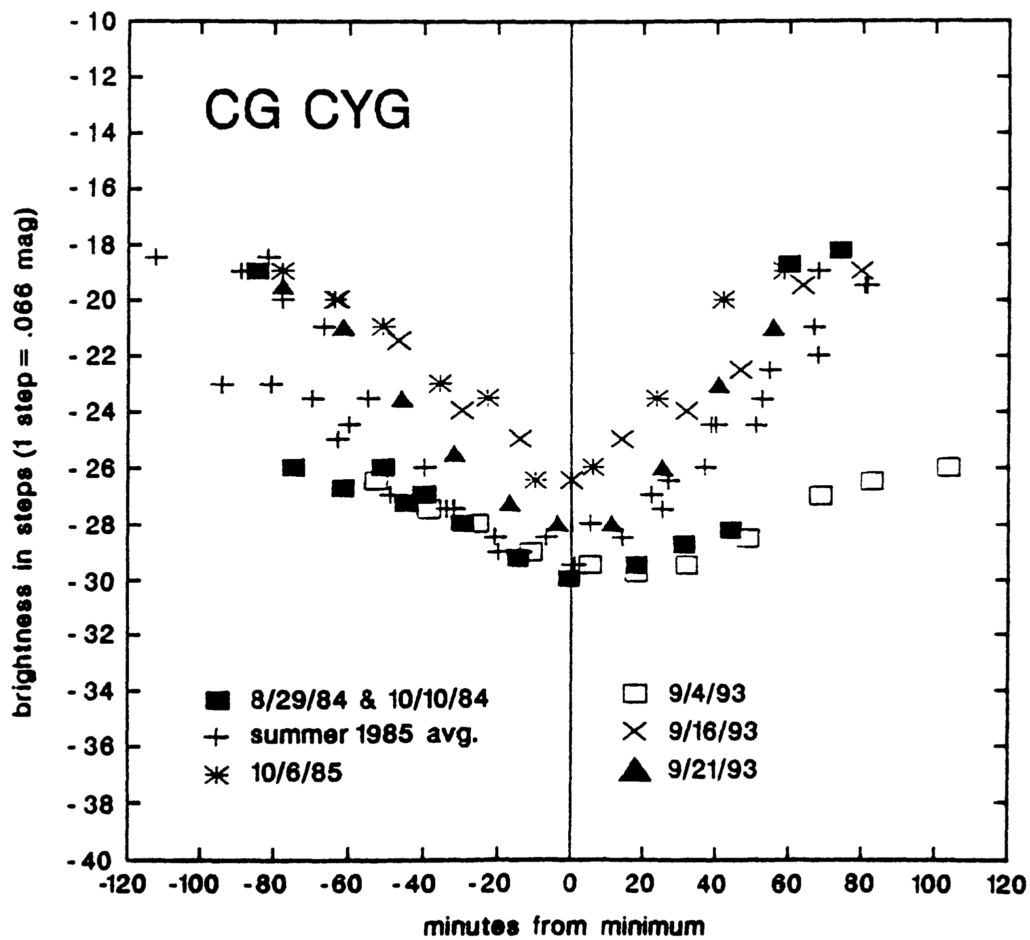

Fig. 1. Visual observations of CG Cyg primary eclipses, 1984-85, 1993.

Table 4. Suggestions of long term variations in EB stars (based on Table 3 data).

EB STAR	TIME FRAME	SUGGESTED CHANGE	ESTIMATED STRENGTH OF OBSERV. EVIDENCE
RT And	1968–1993	max. faded by 0.38 mag.	very weak
AB And	1968–1993	min. faded by 0.33 mag.	weak
		max. faded by 0.25 mag.	
RW Cet	1984–1993	min. faded by 0.38 mag.	fair
YY CMi	1985–1993	min. brightened by 0.46 mag.	weak
		max. may have brightened	
U CrB	1968–1985	min. brightened by 0.30 mag.	weak
V477 Cyg	1985–1993	min. brightened by 0.41 mag.	weak
		max. may have brightened	
FL Lyr	1967–1993	max. faded by 0.35 mag.	weak
		min. faded by 0.28 mag.	
V451 Oph	1985–1993	min. brighter by 0.34 mag.	weak
RS Sct	1984–1992	max. faded by 0.55 mag.	fair to strong
		min. faded by 0.50 mag.	

Table 5. Suggestions of short term variations in EB stars (see * in Table 3 data).

EB STAR	TIME FRAME	SUGGESTED CHANGE	ESTIMATED STRENGTH OF OBSERV. EVIDENCE
XZ Aql	in 2 weeks	minimum brightened by 0.6 mag.	weak
CG Cyg	in 2 weeks	light curve shape changes?	weak to fair
	to a year	(see Figure 1)	
AV Hya	in 3 weeks	minimum brightened by 0.35 mag.	weak
ER Ori	in a year	minimum varied by 0.45 mag	weak
DI Peg	in a year	minimum varied by 0.45 mag.	weak to fair
	in a year	maximum varied by 0.40 mag.	
BU Vul	in a month	light curve shape changes?	weak to fair
		(see Figure 2)	

4. The Importance of EB Intrinsic Variations

To astrophysicists, EB stars are important because they provide the only way to get stellar masses directly along with diameters. They can also serve as "laboratories" in the observational study of stellar evolution. And they can also help us verify fundamental physical laws—for example, a few systems with eccentric orbits can be used to test competing formulations of the theory of general relativity (Guinan and Maloney 1987).

Given the key role that observations of EB stars play in astronomy, detecting and studying intrinsic variations in these objects is important for four reasons. First, in general, such studies can provide additional insight into physical processes associated with the individual component stars, their interaction and their evolution. Second, more specifically, since the most reliable masses and diameters are determined from photometrically uncomplicated EB stars, intrinsic variations can complicate such efforts. Third, in extreme cases, a long-term intrinsic variation could be due to slight changes in a star's diameter or to mass transfer—that is, in studying such phenomena we might be studying unfolding stellar evolutionary processes! Finally, for those EB stars used in testing general relativity (such as EK Cep in Table 3), an undetected intrinsic variation could seriously compromise the results obtained.

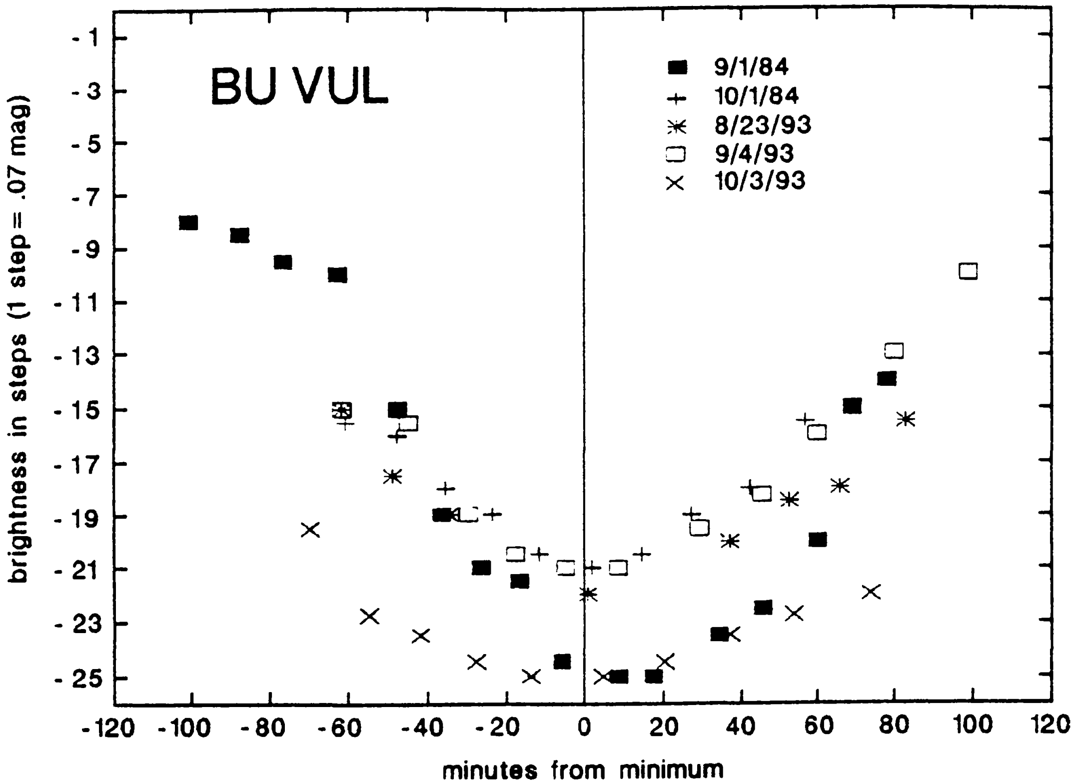

Fig. 2. Visual observations of BU Vul primary eclipses, 1984 and 1993.

5. Conclusion

In theory, detecting larger intrinsic variations in EB stars is possible through careful visual observation. Out of more than 3000 catalogued EB stars, there are undoubtedly some exhibiting intrinsic variations very worthy of detailed study. Conceivably, today's visual (or tomorrow's CCD-equipped) EB star observers, working in conjunction with a group like the AAVSO, could direct professional astronomers to such objects. In practice, it remains to be seen whether these possibilities can be realized.

References

BBSAG 1980, *Bedeck. Beobach. Schweiz. Astron. Gesell.*, **48**, 4.
Cook, S. 1993, *J. Amer. Assoc. Var. Star Obs.*, **21**, 119.
Doyle, J.G., Butler, C.J., Morrison, L.V., and Gibbs, P. 1988, *Astron. Astrophys.*, **192**, 275.
Guinan, E. 1989, in *IAU Colloquium*, No.107, 35.
Guinan, E. and Maloney, F., 1987 in *New Generation Small Telescopes*, Fairborn Observ. Press.
Hall, D. 1991, in *IAU Colloquium*, No. 130, 353.
Hall, D. and Keel, W. 1977, *Acta Astr.*, **27**, 167.
Kholopov, P.N. *et al.* 1985, *General Catalogue of Variable Stars*, 4th ed., Moscow.
Lause, F. 1938, *Astron. Nach.* **265**, 265.
Naftilan, S.A., Grillmair, C., and Trager, G. 1987, *AJ*, **92**, 210.
Nolthenius, R. 1991, *Inform. Bull. Var. Stars*, No. 3589.
Olson, E., Schaefer, B.E., Lines, R., Lines, H., and Fried, R.E. 1992, *Astron. J.*, **103**, 256.
Olson, E. and Etzel, P. 1993, *Astron. J.*, **106**, 342.
Schaefer, B.E. and Fried, R.E. 1991, *Astron. J.*, **101**, 208.
van Ghent, R. 1991, *Astron. Astrophys. Suppl.* **77**, 471.
Williams, D. 1987, *J. Amer. Assoc. Var. Star Obs.*, **16**, 118.
Wood, F. 1963, in *Basic Astronomical Data*, Vol. III, University of Chicago Press.